cta cherenkov telescope array

High-energy transients with CTA

3RD SVOM SCIENTIFIC WORKSHOP, LES HOUCHES,
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THE CTA CONSORTIUM* REPRESENTED BY
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*see http://www.cta-observatory.org/consortium\authors/authors\2018\05.html for full author and affiliation list

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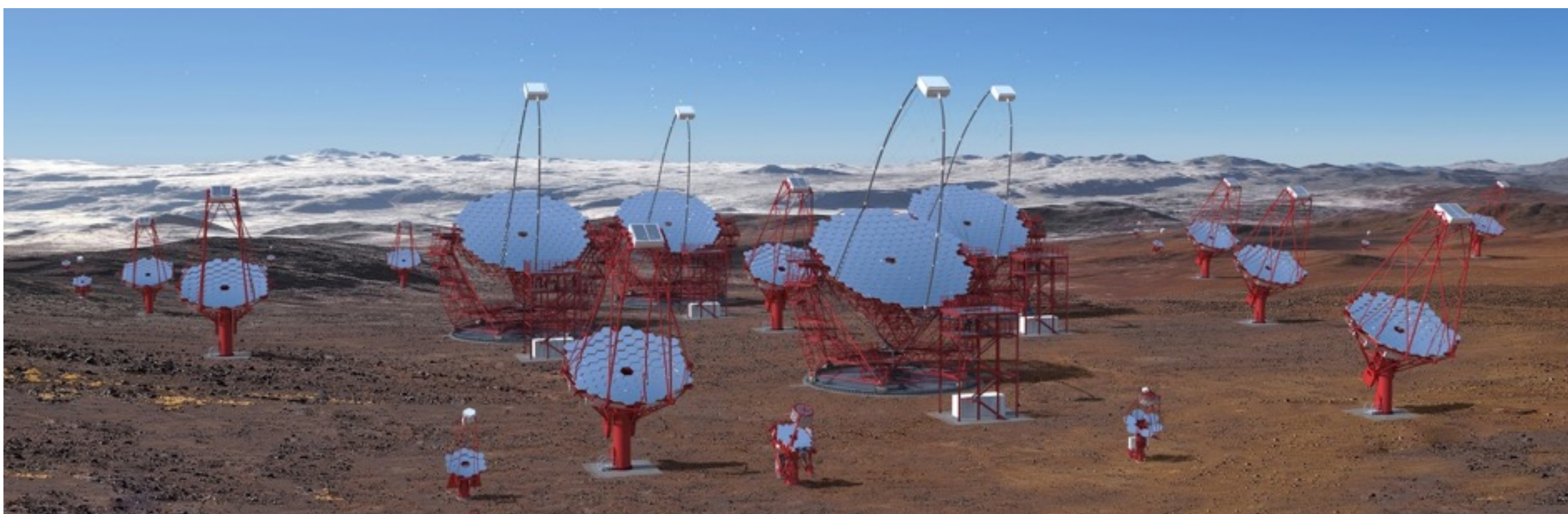
The Cherenkov Telescope Array (CTA)

- **Imaging Atmospheric Cherenkov Telescope (IACT) Array:** observe Cherenkov emission from gamma-ray initiated cascades in the atmosphere

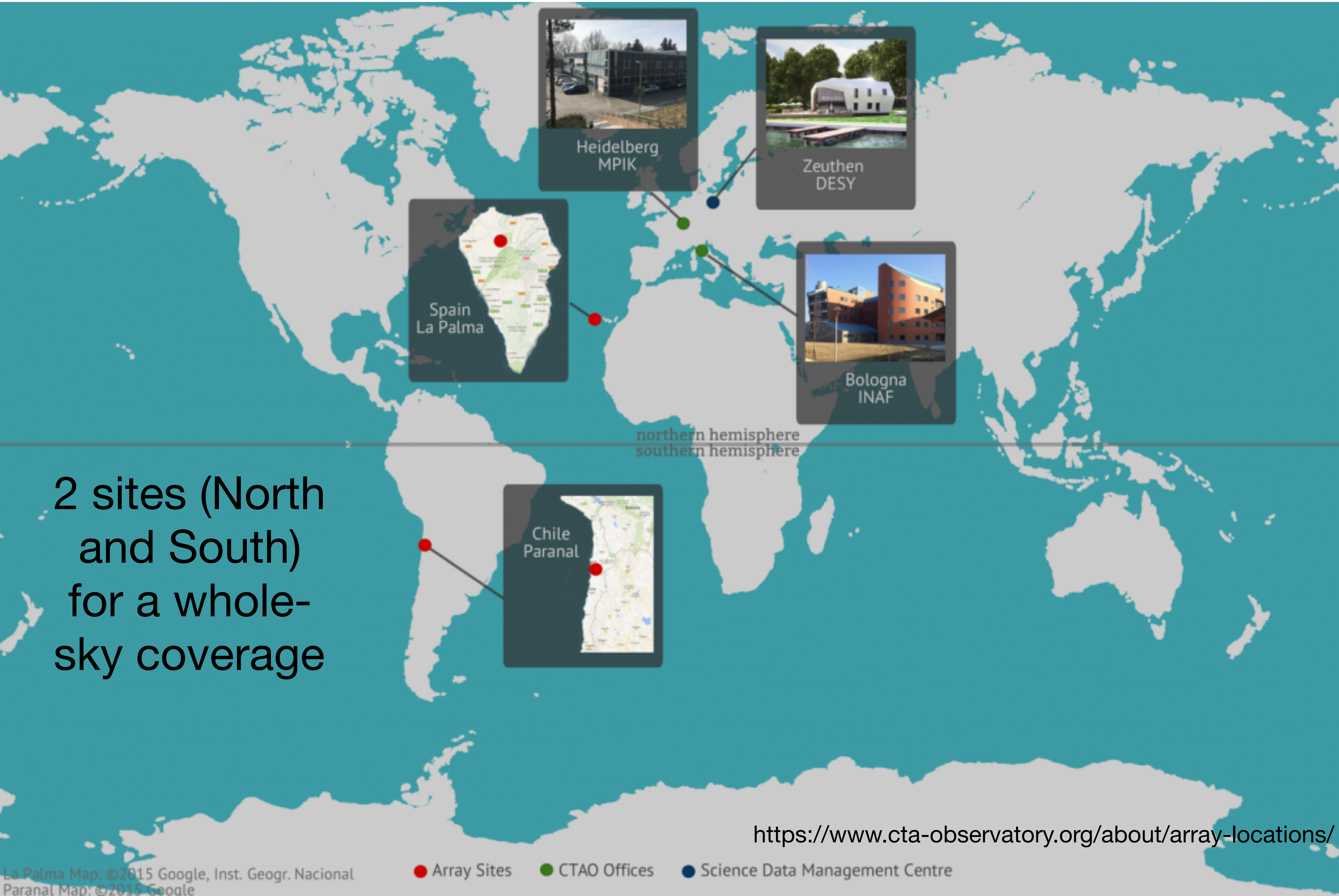
- **Consortium**: 32 countries, 1420 scientists, 210 institutes

- **Observatory**: data openly available after proprietary period, GO programmes, ToOs and DDTs



Southern Hemisphere Site Rendering; credit: Gabriel Pérez Diaz, IAC, SMM

The Cherenkov Telescope Array (CTA)

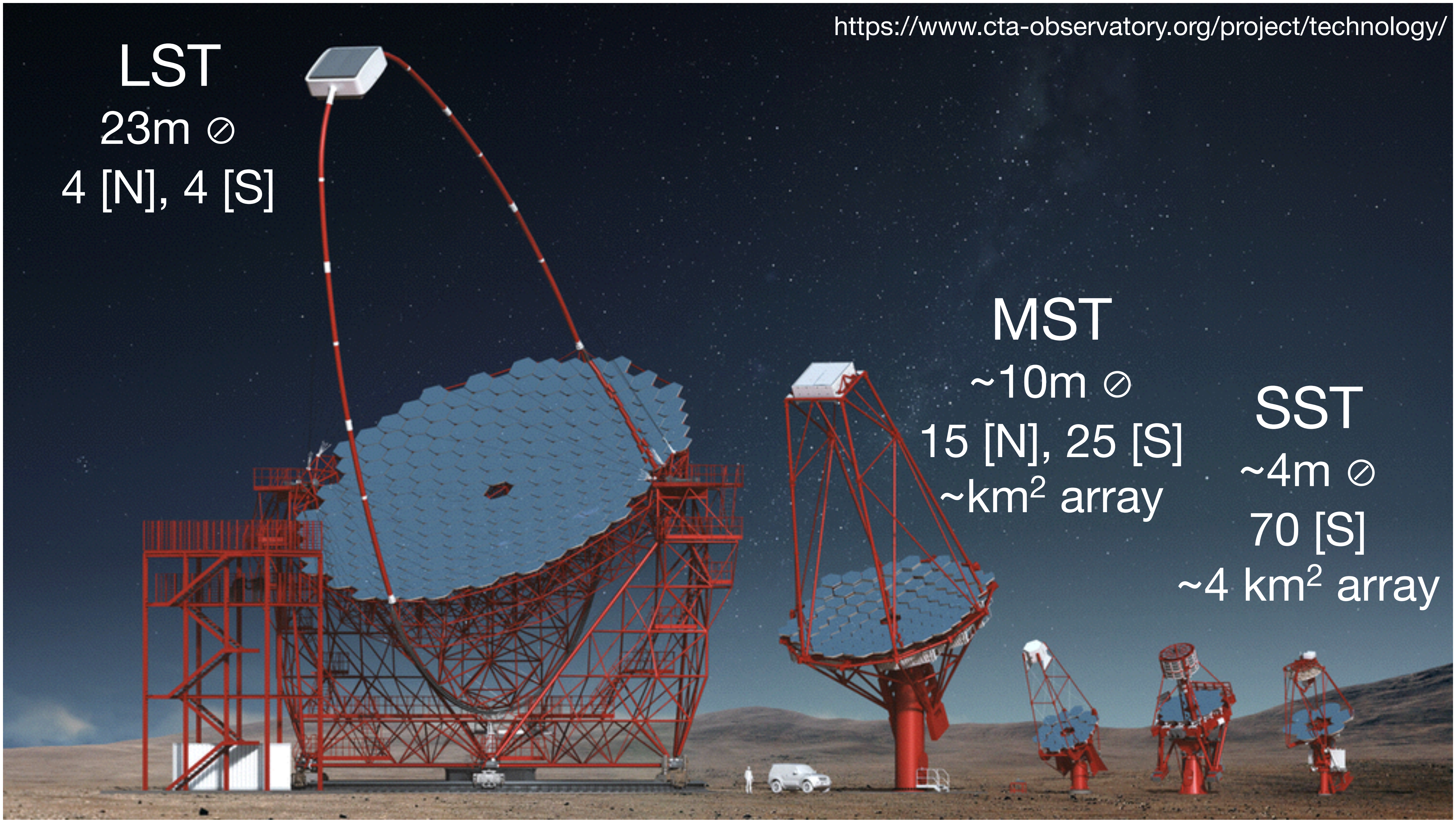


2 sites (North and South) for a whole-sky coverage

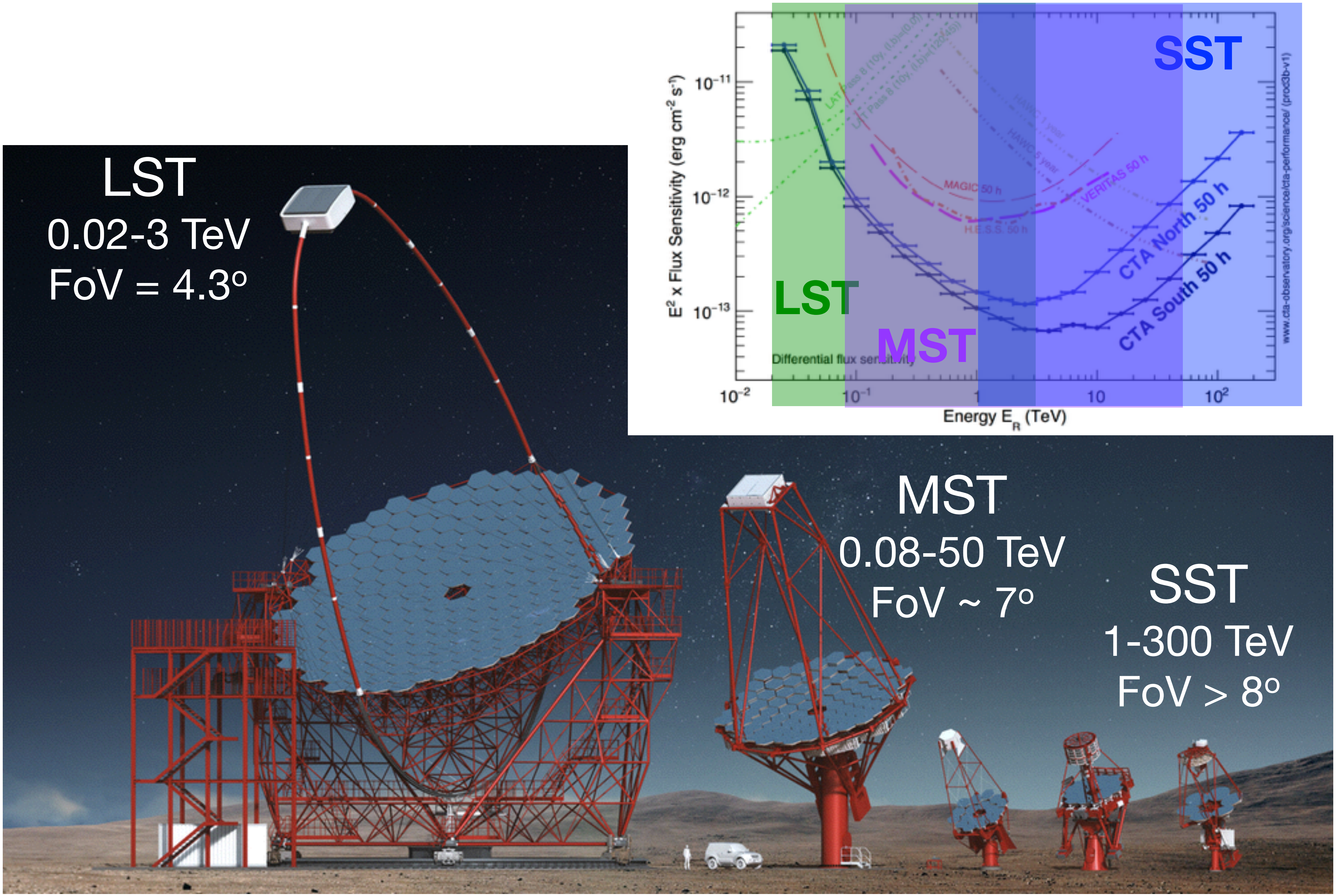
https://www.cta-observatory.org/about/array-locations/

The Cherenkov Telescope Array (CTA)

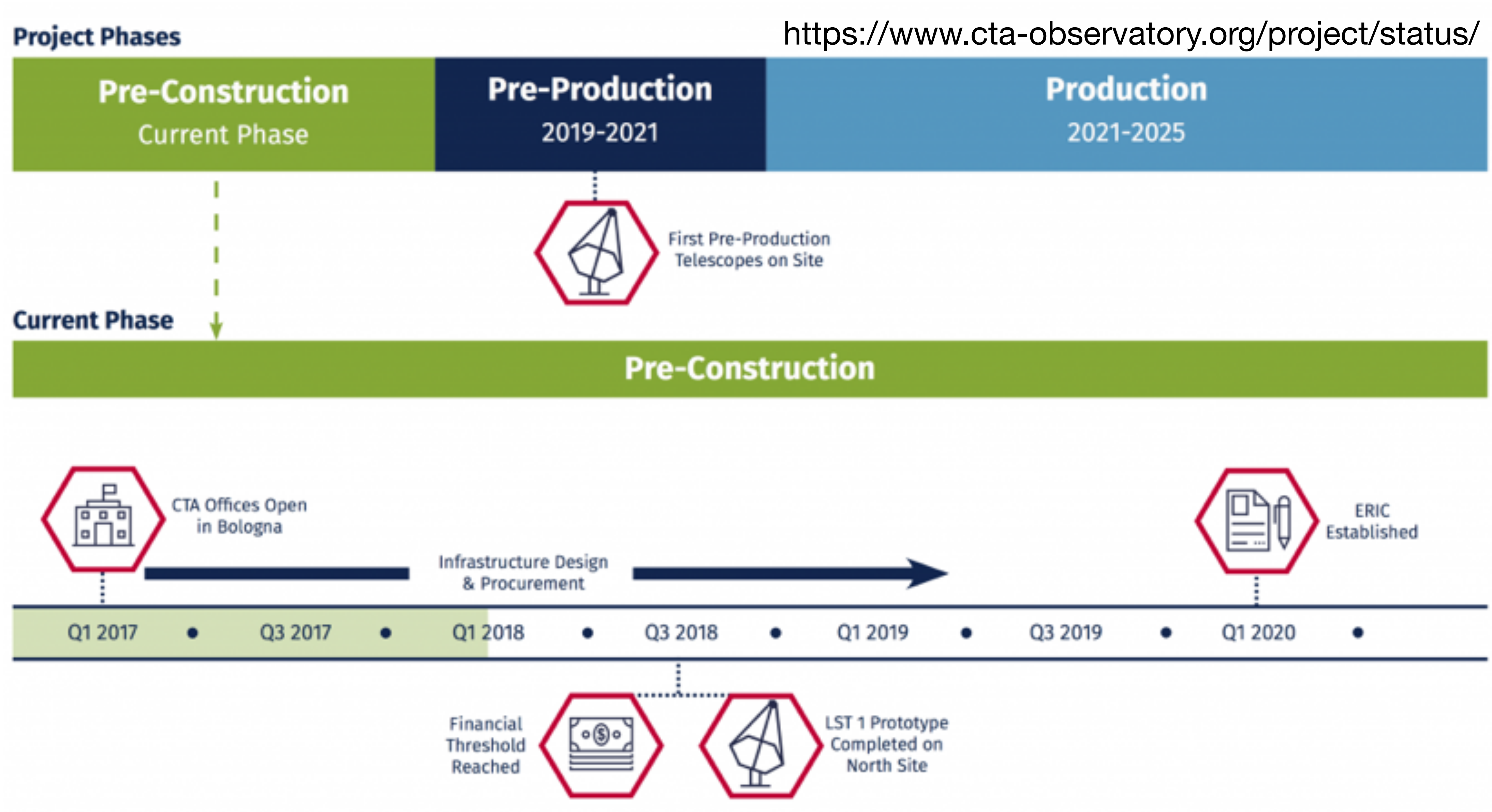
All the systems do not have to point to the same direction



The Cherenkov Telescope Array (CTA)

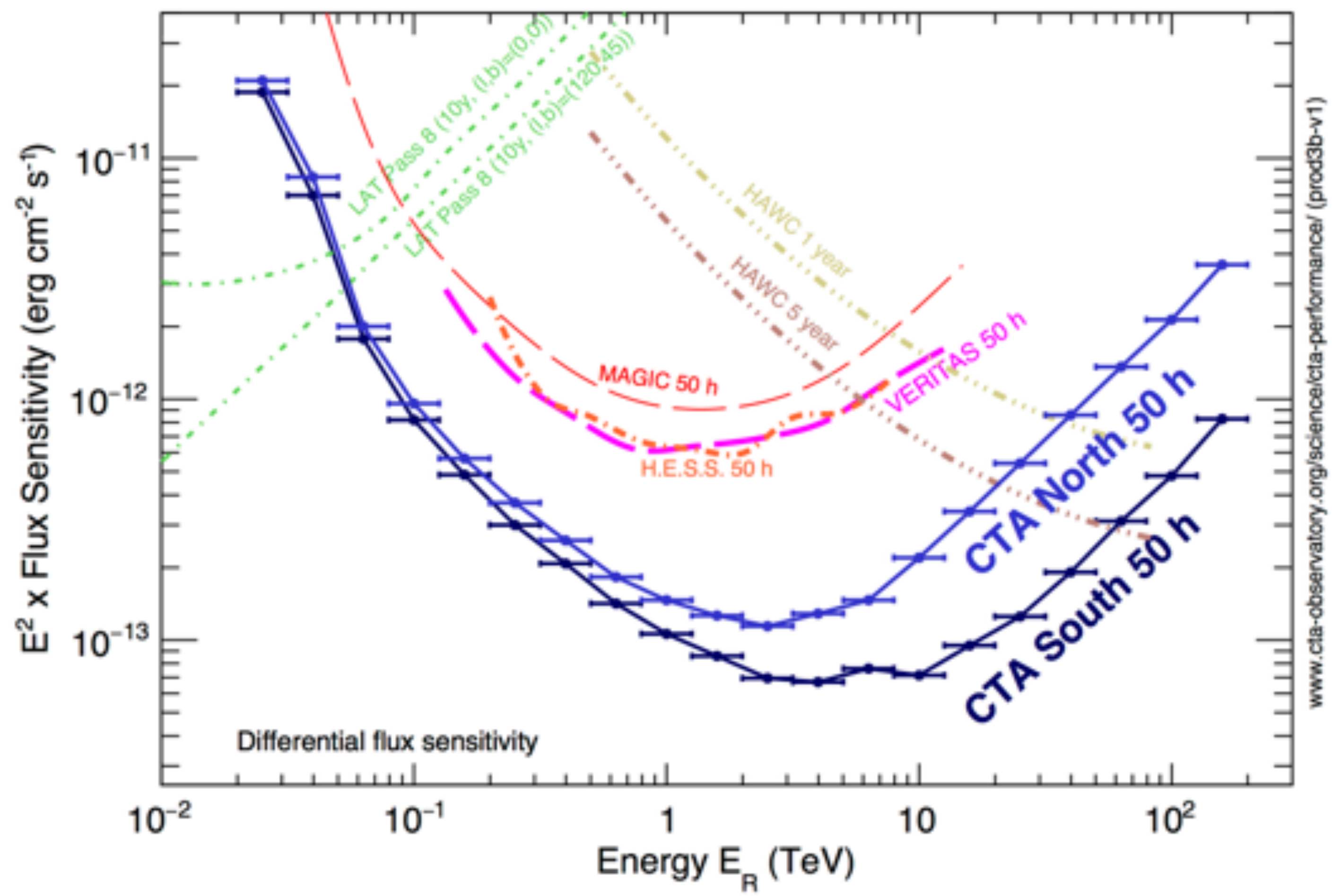


Schedule

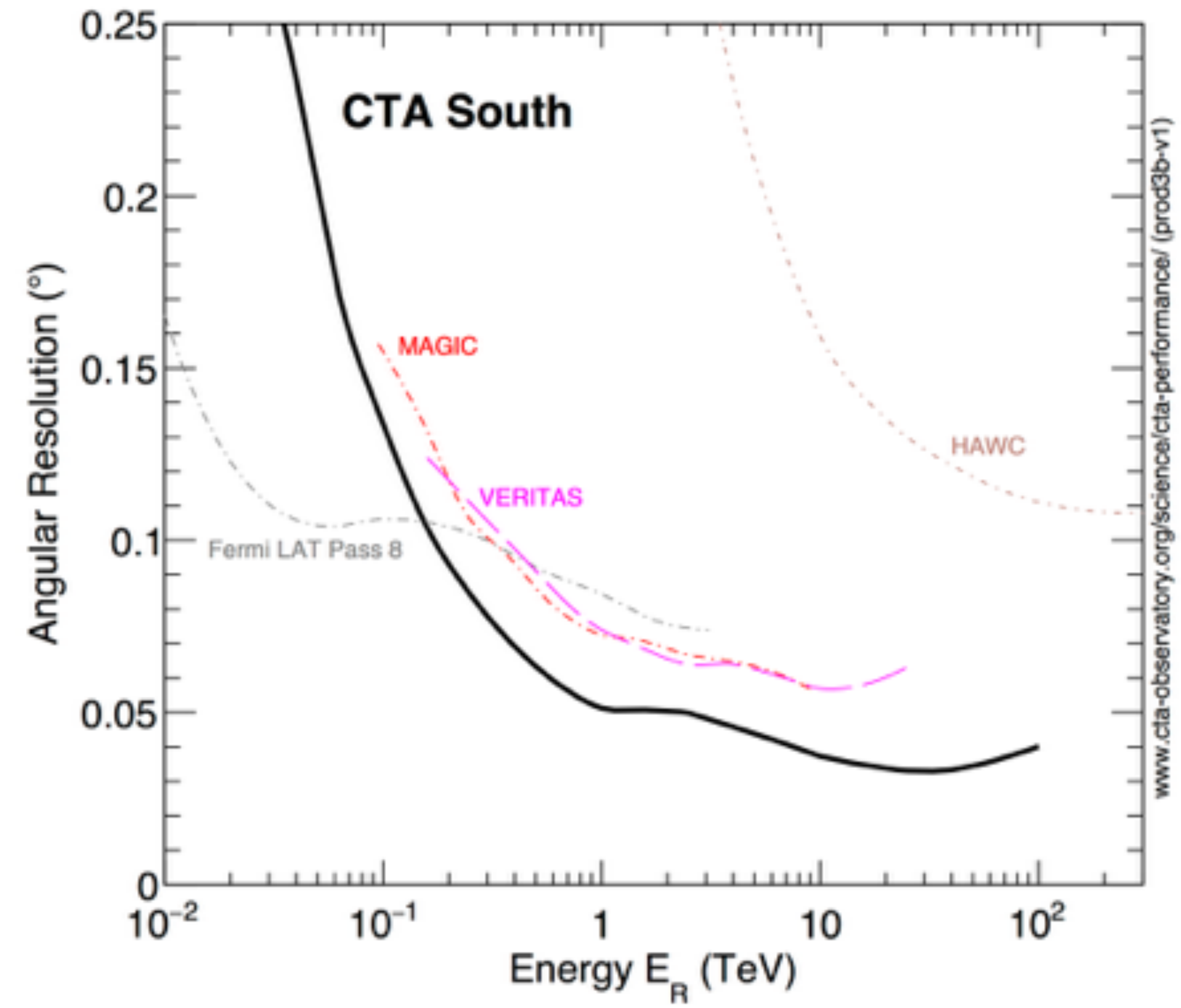


- construction will begin in 2019
- construction period of ~6 years
- initial science with partial arrays possible before the end of construction

CTA expected performance



- **~ 5-20 x more sensitive**, depending on the energy, than the current IACTs
- **broader energy coverage** (20 GeV-300 TeV)



- **better angular resolution** (~3 arcmin at ~ 1 TeV)

CTA science themes

- **Cosmic particle acceleration** (origin, acceleration site and feedback on star formation and galaxy evolution)

- **Probing extreme environment** (processes at the vicinity of NSs and BHs, relativistic jets, winds and explosions)

- **Exploring frontiers in Physics** (dark matter, Lorentz invariance violation)

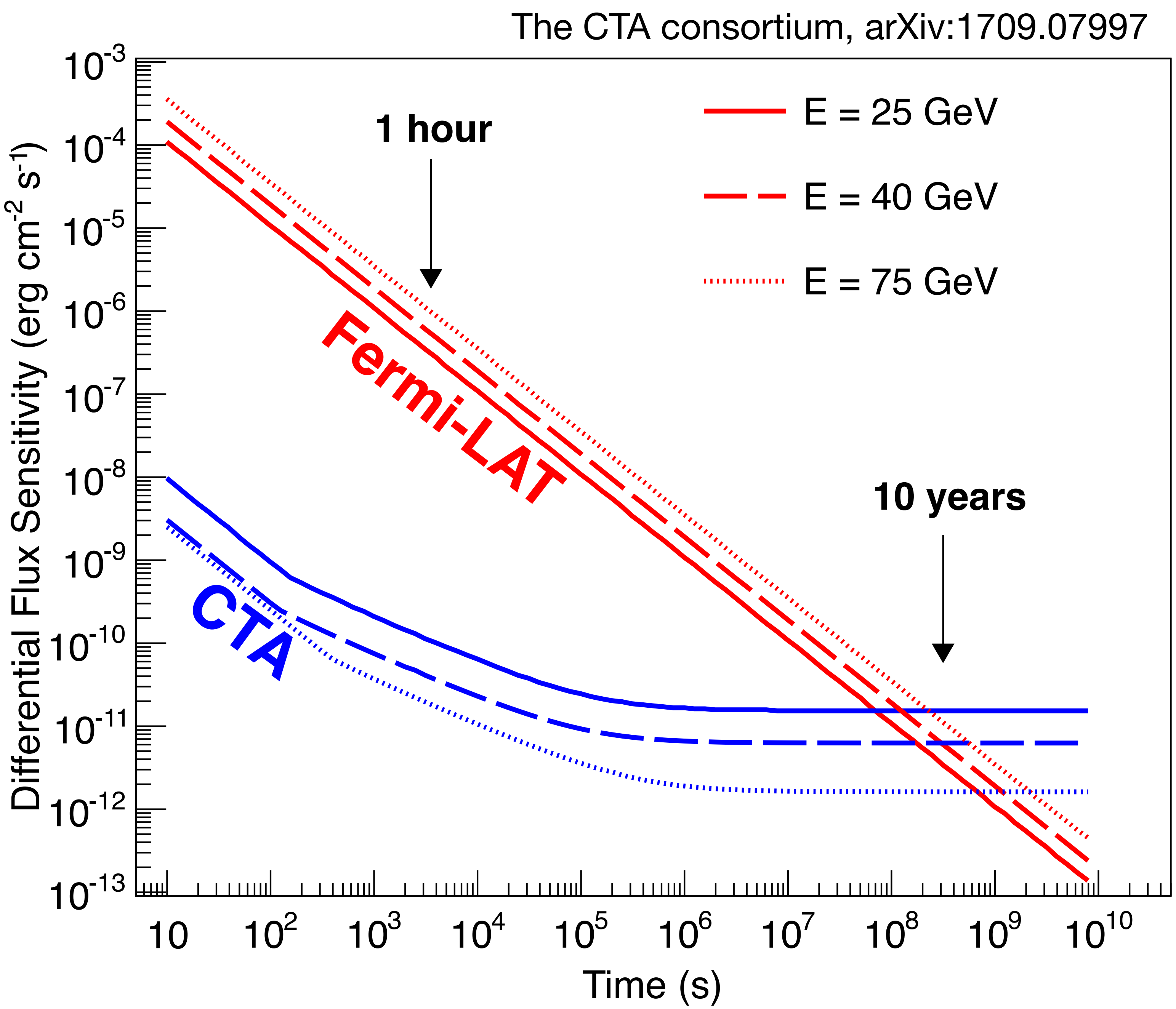
The CTA consortium, arXiv:1709.07997

Key Science projects (KSPs)

Science themes

Theme		Question	Dark Matter Programme	Galactic Centre Survey	Galactic Plane Survey	LMC Survey	Extra-galactic Survey	Transients	Cosmic Ray PeVatrons	Star-forming Systems	Active Galactic Nuclei	Galaxy Clusters
Understanding the Origin and Role of Relativistic Cosmic Particles	1.1	What are the sites of high-energy particle acceleration in the universe?		✔	✔✔	✔✔	✔✔	✔✔	✔	✔	✔	✔✔
	1.2	What are the mechanisms for cosmic particle acceleration?		✔	✔	✔		✔✔	✔✔	✔	✔✔	✔
	1.3	What role do accelerated particles play in feedback on star formation and galaxy evolution?		✔		✔				✔✔	✔	✔
Probing Extreme Environments	2.1	What physical processes are at work close to neutron stars and black holes?		✔	✔	✔			✔✔		✔✔	
	2.2	What are the characteristics of relativistic jets, winds and explosions?		✔	✔	✔	✔	✔✔	✔✔		✔✔	
	2.3	How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?					✔	✔			✔✔	
Exploring Frontiers in Physics	3.1	What is the nature of Dark Matter? How is it distributed?	✔✔	✔✔		✔						✔
	3.2	Are there quantum gravitational effects on photon propagation?						✔✔	✔		✔✔	
	3.3	Do Axion-like particles exist?					✔	✔			✔✔	

The transient sky with CTA



- **improved sensitivity** for short timescales w.r.t. Fermi-LAT in the range of overlap
- **limited FoV** compared to Fermi-LAT
  - ➡**prompt reaction** to external triggers is critical
  - ➡**fast repointing**: 50s for LSTs and 90s for MSTs and SSTs to and from the obs. sky, with the goal to reach shorter slewing times
  - ➡**divergent pointing and tiling observations** (under study)

The Transients key science project

- a programme responding to a **broad range of multi-wavelength and multi-messenger alerts**
- **rapid feedback** to a wide scientific community (selected information communicated in the form of GCNs, Astronomer's Telegrams, IAU circulars) and **rapid response to external alerts**

➡ **characterise different classes of transients:**

- GRBs
- multimessenger (MM) transients
- TDEs, SN shock breakouts, FRBs
- AGN flares
- galactic transients (microquasars, PWN flares, novae, magnetars, X-ray binaries, …)

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- **rapid feedback** to a wide scientific community (selected information communicated in the form of GCNs, Astronomer's Telegrams, IAU circulars) and **rapid response to external alerts**
- specific strategies will be put in place for different classes of transients (for more detailed guidelines see "Science with the CTA", arXiv:1709.07997)

Proposed max obs. time for follow-up targets in the Transients KSP

		Observation times (h yr^{-1} $site^{-1}$)			
Priority	Target class	Early phase	Years 1–2	Years 3–10	Years 1–10
1	GW transients	20	5	5	
2	HE neutrino transients	20	5	5	
3	Serendipitous VHE transients	100	25	25	
4	GRBs	50	50	50	
5	X-ray/optical/radio transients	50	10	10	
6	Galactic transients	150	30	0(?)	
	Total per site (h yr^{-1} $site^{-1}$)	390	125	95	
	Total both sites (h yr^{-1})	780	250	190	
	Total in different CTA phases (h)	1560	500	1520	2020

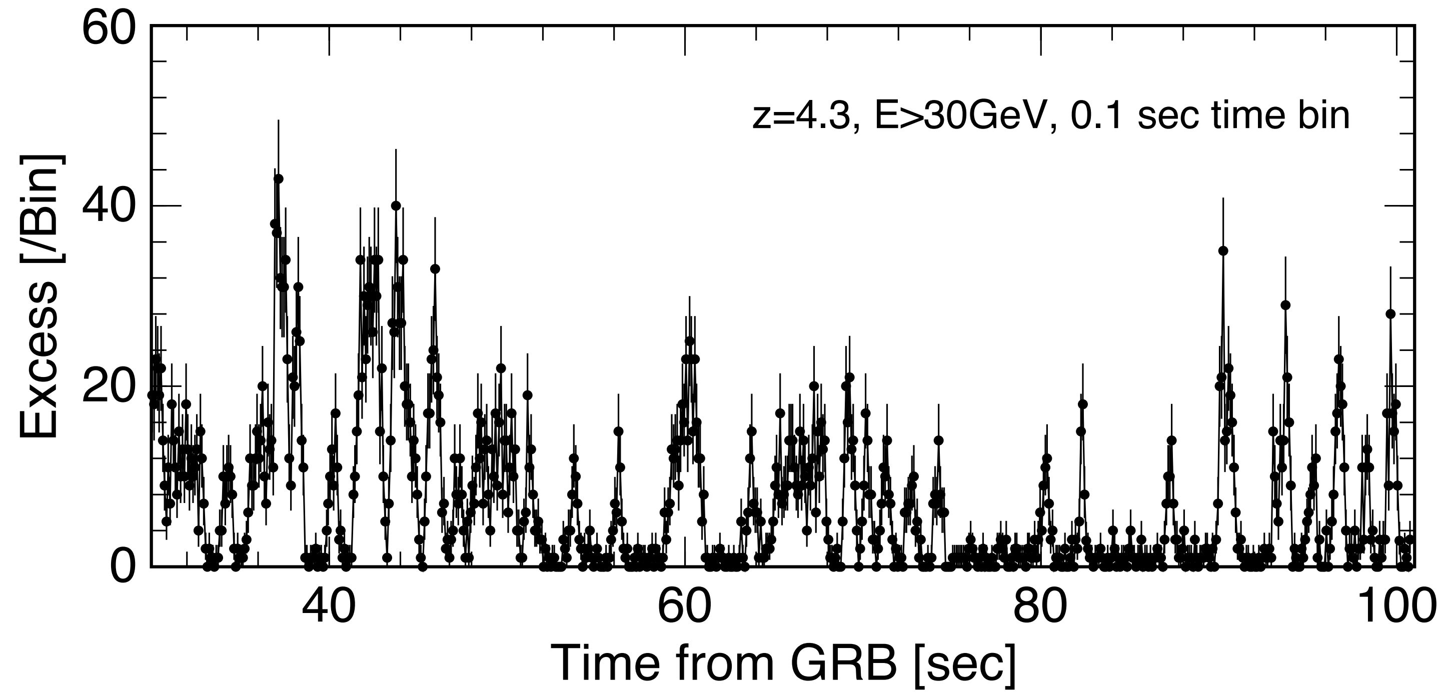
The CTA consortium, arXiv:1709.07997

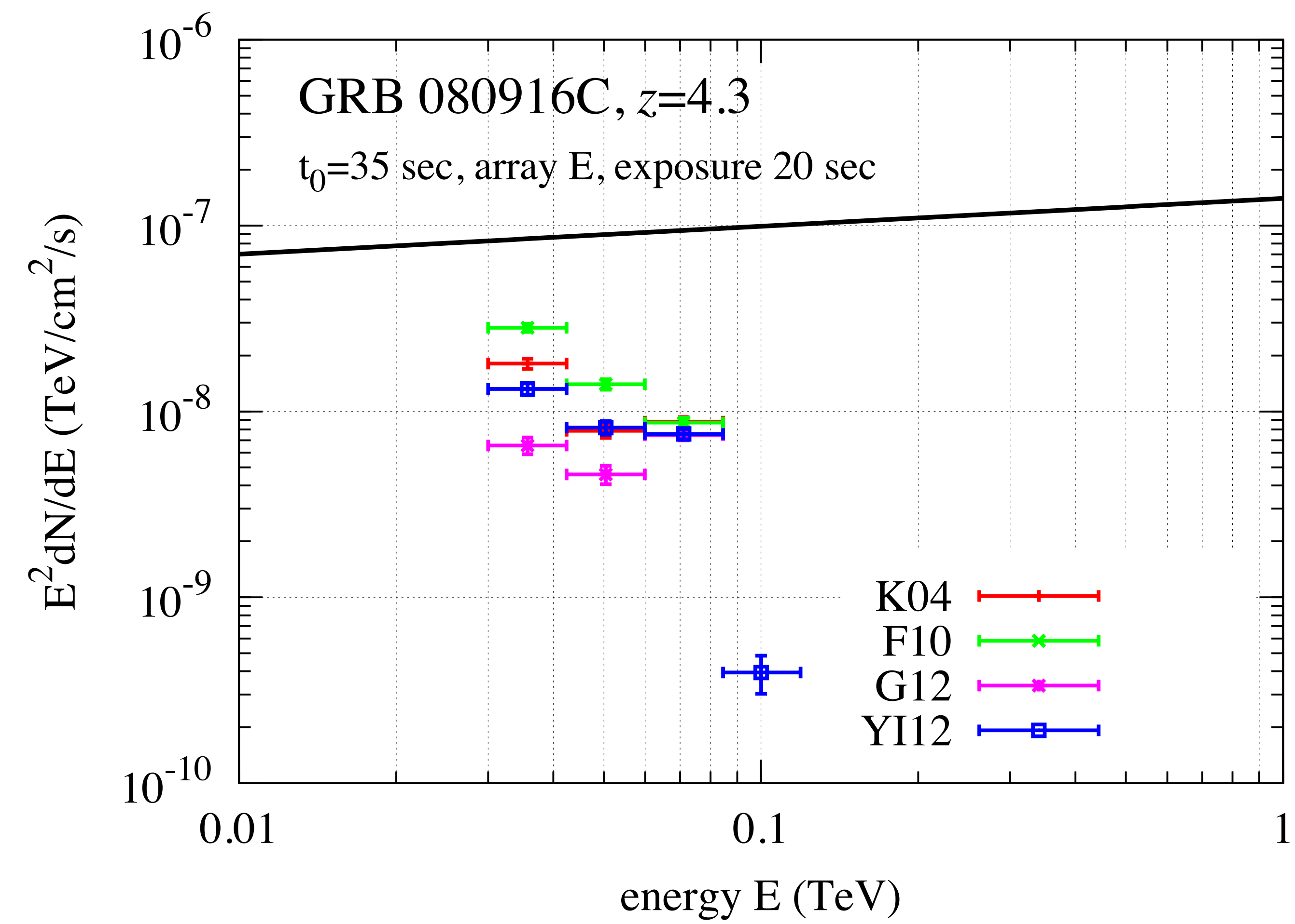
Serendipitously detected transients

- high instantaneous sensitivity + FoV of several degrees
  ➡ **serendipitous discovery of Very High-Energy (VHE) transients during scheduled observations or the galactic and extragalactic surveys** as, e.g.:
    - GRBs in the prompt phase
    - flaring states of known sources (e.g. blazars)
    - unknown VHE transients
- **Real-Time Analysis (RTA)** capable to recognise transients anywhere in the FoV and automatically issue alerts within 30s, with a sensitivity at most 3 times worse than for the final analysis
- once detected, the new transient should be observed as long as possible the same night. Further observations are possible if motivated
- no new VHE transient ever occurred in the FoV during observations of existing IACTs

GRBs with CTA

- expected detection: ~1 GRB/yr/site
- improved photon statistics w.r.t. Fermi/LAT:
  - ➡constrain the high-energy spectral component
    - ✦ high-energy cutoff
    - ✦ measure of the outflow Lorentz factor
  - ➡resolving GRB light curves in more details
    - ✦ variability studies
    - ✦ Lorentz invariance Violation





The CTA consortium, arXiv:1709.07997
Inoue et al., Aph 43, 252, 2013

GRBs with CTA

GRB follow-up strategy:

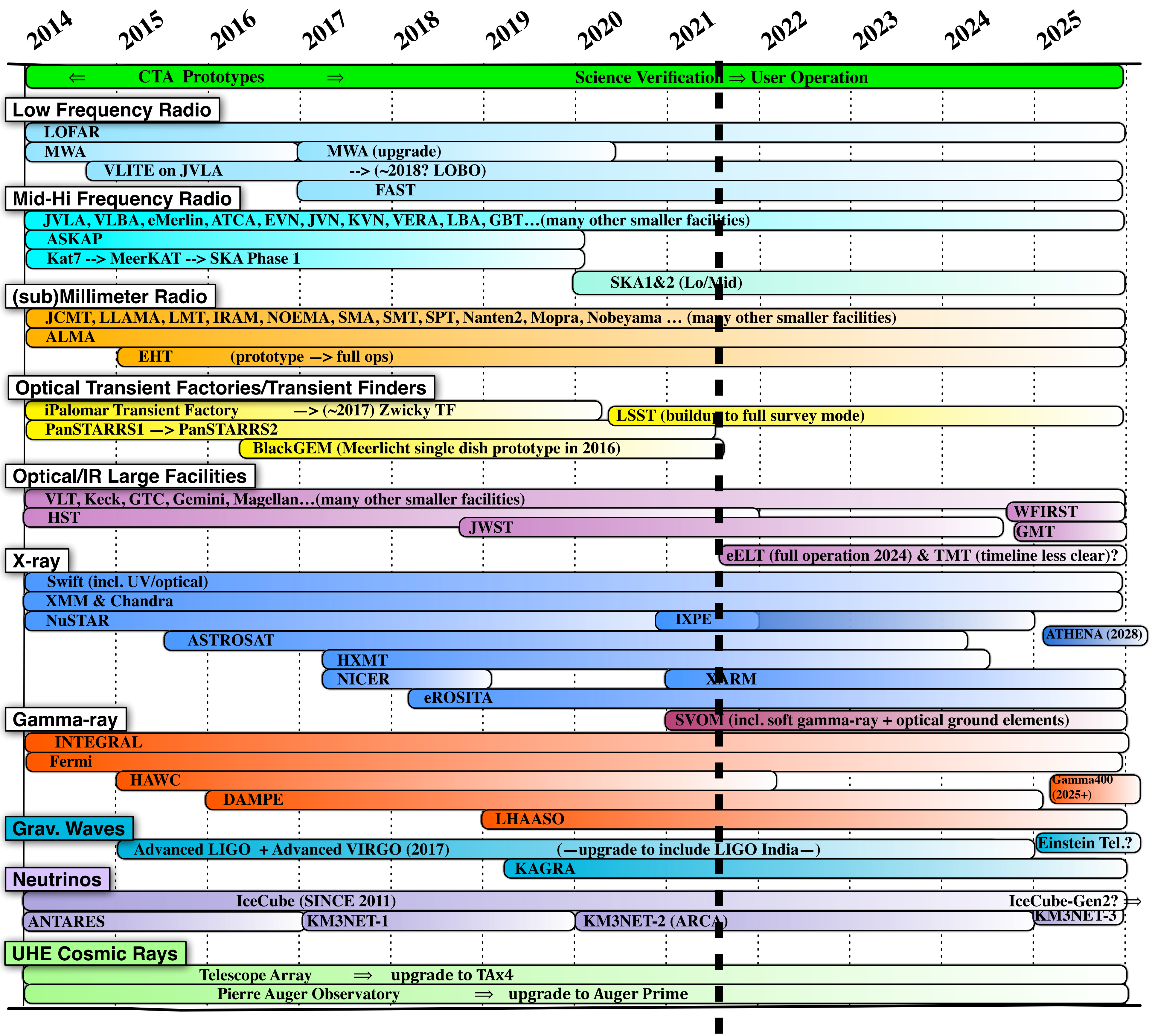
- **prompt follow-up** by the full array **of all accessible GRB alerts**
- possibility to make **tilings** for large areas
- **extended observations for detected GRBs** with the full array
- possible late-time follow-up of high-energy GRBs not accessible promptly

GRB follow-up strategy and obs. time per site

Strategy	Expected event rate (yr^{-1})	Exposure per follow-up (h)	Exposure per year ($h\ yr^{-1}$)
Prompt follow-up of accessible alerts	$\sim$12	2	25
Extended follow-up for detections	0.5–1.5	10–15	10–15
Late-time follow-up of HE GRBs not accessible promptly	$\sim$1	10	10

The CTA consortium, arXiv:1709.07997

Synergies between SVOM and CTA



SVOM will provide to **CTA**:

- external triggers and accurate location for follow-up of high-energy and MM transients
- multi-wavelength characterisation of CTA targets

Synergies between SVOM and CTA

Estimate of the **visibility of SVOM triggers for CTA** (M. Jouret, J. Jaubert):

- ✦ using the SVOM mission simulator developed at CNES (V. Morand)
- ✦ accounting for the delay induced by the delivery of the alerts via the VHF network

Detailed analysis still ongoing. (very) Preliminary results:

- ✦ ~8% GRBs/site detected by SVOM immediately visible by CTA
- ✦ ~65% GRBs alerts distributed within 30 s

➡**~3-4 GRBs/yr/site detected by SVOM immediately visible by CTA with < 30 s delay in the distribution of the alert**

📍Simulation of the population of CTA GRBs as seen by SVOM

➡**how joint SVOM-CTA observations will probe GRB emission**

Conclusions

- CTA will be a versatile telescope for wide range of science topics
- transition from experiment to observatory: open to community access
- improved sensitivity on short timescales w.r.t. Fermi/LAT and other IACTs: probe the transient sky at very high energies
- CTA full potential reached only by strong synergies with multi-wavelength instruments
- SVOM ideal to deliver alerts and accurate location of hard X-ray transients (GRBs, MM emitters, …)